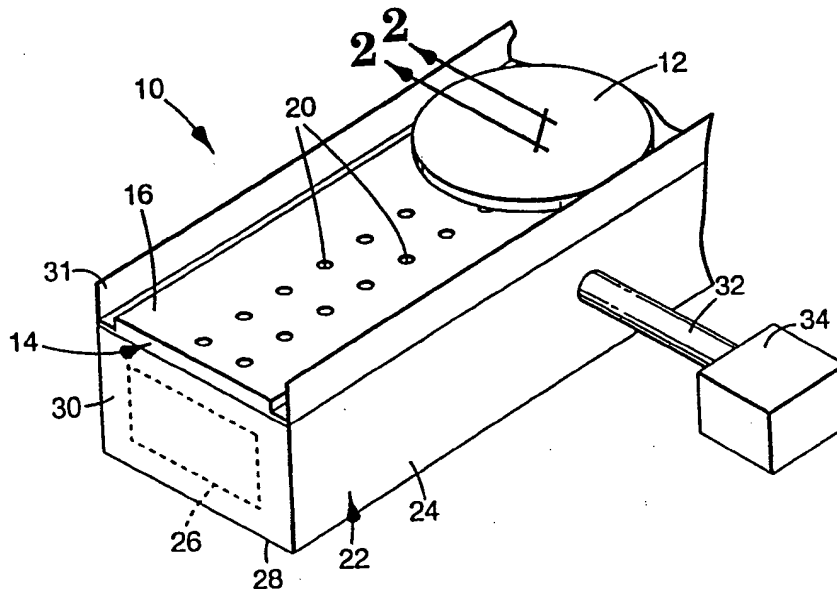




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>5</sup> :</b>  <b>B65G 51/03, H01L 21/00</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 94/02395</b>  <b>(43) International Publication Date:</b> 3 February 1994 (03.02.94)
<b>(21) International Application Number:</b> PCT/US93/06147 <b>(22) International Filing Date:</b> 29 June 1993 (29.06.93)  <b>(30) Priority data:</b> 07/914,775                      15 July 1992 (15.07.92)                      US 08/078,381                      22 June 1993 (22.06.93)                      US  <b>(71) Applicant:</b> MINNESOTA MINING AND MANUFACTURING COMPANY [US/US]; 3M Center, Post Office Box 33427, Saint Paul, MN 55133-3427 (US).  <b>(72) Inventors:</b> SKOW, Lynn, R. ; DUNBAR, William, M. ; Post Office Box 33427, Saint Paul, MN 55133-3427 (US).		<b>(74) Agents:</b> LEVINE, Charles, D. et al.; Office of Intellectual Property Counsel, Minnesota Mining and Manufacturing Company, Post Office Box 33427, Saint Paul, MN 55133-3427 (US).  <b>(81) Designated States:</b> AT, AU, BB, BG, BR, CA, CH, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, LK, LU, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SK, UA, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i>

(54) Title: FLUID TRANSPORT SYSTEM FOR TRANSPORTING ARTICLES



## (57) Abstract

A transport apparatus (10) for transporting articles (12) includes a planar element (14) having a working surface (16, 16A) configured to receive articles (12). Two lines of orifices (19) extend completely through the planar element (14). Fluid delivered through the orifices (19) exits through the outlets (20, 20A) of the orifices (19) in opposite transverse directions and provides a motive force which transports the article (12) while providing a pressure differential which supports the article (12).

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FR	France	MR	Mauritania
AU	Australia	GA	Gabon	MW	Malawi
BB	Barbados	GB	United Kingdom	NE	Niger
BE	Belgium	GN	Guinea	NL	Netherlands
BF	Burkina Faso	GR	Greece	NO	Norway
BG	Bulgaria	HU	Hungary	NZ	New Zealand
BJ	Benin	IE	Ireland	PL	Poland
BR	Brazil	IT	Italy	PT	Portugal
BY	Belarus	JP	Japan	RO	Romania
CA	Canada	KP	Democratic People's Republic of Korea	RU	Russian Federation
CF	Central African Republic	KR	Republic of Korea	SD	Sudan
CG	Congo	KZ	Kazakhstan	SE	Sweden
CH	Switzerland	LI	Liechtenstein	SI	Slovenia
CI	Côte d'Ivoire	LK	Sri Lanka	SK	Slovak Republic
CM	Cameroon	LJ	Luxembourg	SN	Senegal
CN	China	LV	Latvia	TD	Chad
CS	Czechoslovakia	MC	Monaco	TG	Togo
CZ	Czech Republic	MG	Madagascar	UA	Ukraine
DE	Germany	ML	Mali	US	United States of America
DK	Denmark	MN	Mongolia	UZ	Uzbekistan
ES	Spain			VN	Viet Nam
FI	Finland				

FLUID TRANSPORT SYSTEM FOR  
TRANSPORTING ARTICLES

5     Technical Field

          The present invention relates to a transport system for moving articles. More particularly, the present invention relates to a fluid transport system for moving articles in a controlled manner with the article held adjacent the transport by the conveying fluid.

Background of the Invention

          Devices such as air tables which provide a cushion of air on which an article can float are well known. Air conveyers which use air flow to impart translational movement while floating the article along a plane parallel to a surface also are well known.

          Transport tables which use directional air jets to transport articles also are known. For example, Hassan et al., U.S. Patent No. 4,081,201, Loveless et al., U.S. Patent No. 4,278,366, and DeRobertis et al., U.S. Patent No. 4,395,165 disclose transporting computer chips and wafers using an air film at low speeds and with the air exiting the system at a large acute angle with respect to the surface along which the chips and wafers are transported. Futer, U.S. Patent No. 3,180,688, Lasch, Jr. et al., U.S. Patent No. 3,645,581, Range, U.S. Patent No. 3,614,168 and Lasch, Jr., U.S. Patent No. 3,718,371 are representative of patents that disclose various conveyors which use air which exits the system at smaller acute angles less than 30° with respect to the surface along which the articles are transported. Wallin et al., U.S. Patent No. 3,231,165 discloses an air conveyor for transporting flexible webs which uses outwardly oriented air outlets. This system requires backwardly facing outlets to help stretch taut the

-2-

webs as well as a segmented surface to exhaust the transport air. These systems are relatively complex, and simpler and more efficient systems are desired.

None of the known systems discloses a fluid transport apparatus which can transport articles including flexible webs in which the working surface, adjacent which articles are transported, is continuous and substantially smooth to permit fluid delivered to the working surface to exhaust off of the working surface at the side edges of the working surface. None of these systems discloses a fluid transport system in which the fluid is delivered to the working surface along first and second arrays which are located on opposite sides of the longitudinal centerline of the working surface to transport flexible articles, with each of the outlets oriented to deliver fluid at an outward angle with the direction of transport to prevent impingement of the fluid flows from the two arrays, without requiring backwardly directed air flow from backwardly directed outlets. None of these systems disclose outlets which can have relatively small length-to-width ratios while ejecting air at small acute angles, and none discloses outlets that create an angular, non-linear, stepped path for the fluid.

#### Summary of the Invention

The present invention is a transport system for transporting articles which improves upon known transport systems. The transport system transports the article while the article is held to the transport surface without contact and with control of the article. The article can be transported in any orientation.

The transport system has a working surface having a longitudinal centerline and two side edges, The working surface is continuous and substantially

-3-

smooth to permit fluid delivered to the working surface to exhaust off of the working surface at the side edges of the working surface. The article is transported and supported along the working surface by a plurality of orifices terminating in outlets on the working surface. The outlets deliver the fluid to the working surface along first and second arrays which determines the transport path of the article.

The first and second arrays are located on opposite sides of the longitudinal centerline of the working surface and each of the outlets is oriented to deliver fluid at an angle with the direction of transport. The fluid flow direction includes a cross-directional component perpendicular to the direction of transport and a directional component parallel to the direction of transport. The fluid flow from the outlets of the first array does not impinge the fluid flow from the outlets of the second array adjacent the working surface. The fluid exiting the outlets transports the article along the working surface and supports the article adjacent and spaced from the working surface while preventing the article from contacting the working surface during transport.

#### Brief Description of the Drawings

Figure 1A is a schematic perspective view of a transport system of the present invention. Figure 1B is a schematic cross-sectional view of the transport system.

Figure 2 is a cross-sectional view of the transport system of the present invention taken along the array of outlets of Figure 1.

Figure 3 is a partial cutaway top view of the transport system of Figure 1.

Figure 4 is a schematic view of a horizontal one-dimensional, transport path.

Figure 5 is a schematic view of a curved,

-4-

two-dimensional transport path.

Figure 6 is a schematic view of a helical, three-dimensional transport path.

Figure 7 is a schematic view of an upside-down, horizontal, one-dimensional transport path.

Figure 8 is a schematic view of a downwardly vertical transport path.

Figure 9 is a schematic view of an upwardly vertical transport path.

Figure 10 is a schematic perspective view of an alternative embodiment of the transport system of the present invention.

Figure 11 is a schematic view of the transport system of Figure 10.

Figures 12A and 12B are cross-sectional views of an alternative embodiment of the transport system of the present invention.

Figure 13 is a schematic cross-sectional view of the transport system showing the transfer of an article from one transport system to another transport system.

#### Detailed Description of Preferred Embodiments

The transport system 10 of the present invention is illustrated in Figures 1-3. The transport system 10 can transport articles 12 without contacting the article. The system 10 can transport articles, including webs such as tape, provided the article has an area-to-weight ratio large enough to be supported via a pressure differential and transported by a given transport system. The transport system 10 can operate with various fluids including air, water, inert fluorocarbons, and various other gases and gas mixtures. The transport system 10 includes a planar element 14, such as a top plate, having a working surface 16 and an opposing surface 18. The articles

-5-

12 are transported in a preferred direction as the working surface 16 operates on the articles 12. The working surface 16 may be planar or curved, providing one-dimensional (Figure 4), two-dimensional (Figure 5), or three-dimensional (Figure 6) article paths, depending on the specific application.

As shown in Figure 1A, a plurality of orifices 19 having outlets 20 are in fluid communication with a conduit assembly 22. The orifices 19 serve as an outlet for a conduit assembly 22, extend through the planar element 14, and are arranged in two arrays of outlets 20 on the working surface 16, although a single array or many arrays also can be used. As shown, the arrays can be linear. As shown in Figure 1B, which is a generalized schematic illustration of the orifice, each orifice 19 extends through the planar element 14 at an acute angle  $\alpha$ , relative to the working surface 16. The outlet 20 of each orifice 19 is also oriented to cause the fluid to exit the outlet 20 at the same angle  $\alpha$  with the working surface 16. A pair of outlets 20, each in a respective array of outlets, as shown in Figure 1A, are spaced from each other at a given preferred location. As described below, the location of the arrays of outlets, and the distance between adjacent outlets 20 in an array and adjacent outlets 20 in adjacent arrays can be selected based on the size of the article 12 being transported. The distance, perpendicular to article movement, between adjacent outlets 20 at the same location is selected based on the size of the article 12. For a 3.5 inch magnetic disk, this distance is 1.27 cm (0.5 in). The distance, parallel to article movement, between adjacent outlets 20 in an array of outlets is also selected based on the size of the article 12 and is 1.90 cm (0.75 in) for a 3.5 inch magnetic disk.

The conduit assembly 22, shown in Figure 1A,

-6-

includes a housing 24 mounted to the opposing surface 18 of the planar element 14. The housing 24 includes a channel which defines a plenum chamber 26 and has a bottom wall 28 and side walls 30, and a top wall  
5 formed by the opposing surface 18 of the planar element 14. At least one side wall 30 includes edge guides 31 extending above the working surface 16 to guide the article 12 as it is transported. An inlet 32 extends into the housing 24 and introduces fluid to  
10 the plenum chamber 26 for distribution through the orifices 19. The inlet 32 is coupled to a pressurized fluid supply 34 which supplies a fluid to the conduit assembly 22.

The pressurized fluid within the plenum  
15 chamber 26 exits through the outlets 20 to deliver a jet-like flow of fluid against the article 12 to provide a motive force to transport the article 12. The jet-like fluid flow creates a pressure differential upon which the article 12 is supported.  
20 The pressure differential results in a fixed gap between the working surface 16 of the planar element 14 and a bottom surface 36 of the article 12. The fixed gap is established by balancing and maintaining equilibrium among the forces, including gravity, on  
25 the article 12.

The transport characteristics of the article 12 can be altered by changing the angle  $\alpha$  as well as the angle  $\beta$ , shown in Figure 3. As the angle  $\beta$  decreases from  $90^\circ$  to  $0^\circ$ , the pressure differential  
30 between the top and bottom surfaces of the article 12 is increased and the article velocity decreases. Figures 2 and 3 illustrate a layered construction of a planar element 14.

The layered construction as shown in Figure  
35 3 can be formed of materials that are rigid or flexible and the layers can be laminated to each other. There can be as many layers as are necessary



-7-

to create the desired outlet configuration within the space constraints of overall thickness and individual layer thickness. Figure 3 illustrates a three layered construction of a planar element 14. The first layer 52 is the inlet or supply layer and includes an opening 54 which serves as the fluid inlet 32. The second layer 56 is a directional layer which includes elongate orifices 58 which are oriented generally in the direction of flow and distribute the fluid in the direction of flow. In this embodiment, these openings 58 define the interior region plenum chamber of the conduit assembly housing. The third layer 60 includes the working surface 16 and outlets 20 of the orifices 19 through which the fluid exits. The opening 54, orifice 58, and outlet 20 combine to form the orifice 19. As is shown in the Figures, each outlet can create an angular, non-linear, stepped path for the fluid.

As shown, the transport system 10 can have a continuous, smooth working surface 16, with no breaks in the surface other than the outlets 20, and with no protrusions, such as edge guides at the side edges. Alternatively, grooves and other minor surface features can be formed in the working surface, but these are not necessary to exhaust fluid. The presence of these surface features makes the working surface substantially smooth. Also, the working surface is at least as long as the articles being transported. The working surface 16 has a longitudinal centerline between the two side edges and need not be segmented to facilitate the exhaust of the fluid. The fluid that is delivered to the working surface exhausts at the side edges of the working surface or at the side edges of the article, depending on whether the article is wider than the working surface.

The first and second arrays of outlets are

-8-

located on opposite sides of the longitudinal centerline of the working surface 16. Each of the outlets is oriented to deliver fluid at an angle with the direction of transport, as shown in Figure 1A.

5 The directional component 66 of the fluid flow contributes to both the pressure differential and transport of the article 12 while the cross-directional component 62, perpendicular to the directional component 66, contributes only to the  
10 pressure differential. The directional and cross-directional components 62, 66 combine to yield the flow direction 64. When the fluid exits with no cross-directional component 62 the system 10  
15 transports articles 12 with less pressure differential than if there were a cross-directional component. When the fluid exits with no directional component 66, the system 10 holds articles 12 with no transport and no contact.

As shown, the direction of the  
20 cross-directional component 62 of the fluid flow direction of each outlet 20 in the first array of outlets is away from that of each outlet 20 in the second array of outlets. This orifice orientation permits the system 10 to stretch flexible articles  
25 taut, permitting the transport of webs without fluttering or other instability. The perpendicular distance from the first and second arrays of outlets 20 to the respective working surface side edges is selected to assist exhausting of the fluid off of the  
30 working surface at the side edge of the working surface. Additionally, the outlets can all be oriented with the directional component of the fluid flow in the direction of article transport. No backwardly-facing outlets are required to stretch taut  
35 flexible articles.

Holes may be formed by drilling with a bit having a circular cross section and, when drilling at

-9-

an acute angle with the plane of the working surface, form an outlet at the working surface having an oval cross section with a length-to-width ratio governed by the drilling angle  $\alpha$  as expressed in the equation  $l/w = 1/\sin \alpha$ . However, the outlet area can have any shape. It could be rectangular, round, oval, or any regular or irregular polygon. The outlet length-to-width ratio is not limited by the drilling angle formula and length-to-width ratios much less than dictated by the formula can be achieved. Thus, the outlet 20 can extend through the working surface 16 to deliver fluid to the working surface at an effective angle of less than  $20^\circ$  with an outlet having a length-to-width ratio less than 2.9. The effective angle can be less than  $15^\circ$  and the length-to-width ratio less than 3.8, the effective angle can be less than  $10^\circ$  and the length-to-width ratio less than 5.7, and the effective angle can be less than  $5^\circ$  and the length-to-width ratio less than 11.4.

According to the Bernoulli principle, as the fluid velocity increases, its pressure is reduced from that of the surrounding fluid moving at a lower velocity. The velocity difference causes a pressure difference. An object placed between the high and low velocity fluid will tend to be forced toward the higher velocity fluid until equilibrium is reached. Where a uniform fluid flow is forced between a stationery plate and a movable object, a uniform force will be exerted on the object toward the plate. The object will not contact the plate if the object has an area-to-weight ratio large enough so that the upward force from the fluid jets equals or exceeds the gravitational force and other attractions.

As long as the fluid flow is uniform between the article 12 and the working surface 16 and the article 12 has a sufficiently large area-to-weight ratio, pressure will be exerted on the article toward

-10-

the working surface. Therefore, the system 10 can operate in any orientation both relative to the web travel direction as well as relative to the cross-web direction. The system 10 can operate when the planar element 14 and the article 12 are horizontal with the article 12 on top of the working surface 16 of the planar element 14 (Figure 4), as well as vertical (Figures 8 and 9), with the article 12 underneath the working surface 16 of the planar element 14 (Figure 7), or at any orientation along the 360° circle of positions. The system 10 is orientation independent.

An alternative transport system 10A is shown in Figure 10. The transport system 10A includes a planar element having a working surface 16A. In this embodiment, the planar element is simply a planar surface. The planar element includes first and second arrays of outlets 20A and a third array of outlets 40. All of the outlets 20A, 40 extend through the planar element at an acute angle relative to the working surface 16A. The third array of outlets 40 is directed opposite to the first and second arrays of outlets 20A. The third array of outlets 40 can be centrally located along a central longitudinal axis of the working surface 16A while the first and second arrays of outlets 20A can include two arrays running along each transverse side of the working surface 16A. The distance, parallel to article movement, between adjacent outlets 40 is selected based on the size of the article 12, the flow rate, and the orifice angle, and is 1.90 cm (0.75 in) for a 3.5 inch magnetic disk.

The conduit assembly 22A is in fluid communication with the first and second arrays of outlets 20A, 40. The housing 24A includes a first channel that defines a first plenum chamber 26A positioned beneath the first and second arrays of outlets 20A. A second annular channel of the housing 24A defines a second plenum chamber 42 positioned

-11-

beneath the third array of outlets 40.

As shown in Figures 10 and 11, first and second inlets 32A, 44, respectively, extend through the housing 24A into the respective first and second plenum chambers 26A, 42. The first and second inlets 32A, 44 are coupled to respective compressed fluid supplies 34A, 46 which supply fluid under pressure to the plenum chambers 26A, 42, which can operate under different pressures. Fluid delivered to the first plenum chamber 26A exits through the first and second arrays of outlets 20A and provides a motive force to transport the article 12. Fluid delivered under pressure to the second plenum chamber 42 exits through the third array of outlets 40 and provides a braking force that counteracts the motive force and thereby controls the speed of transport. This fluid also can provide an increased pressure differential between the article 12 and the surface 16A. Alternatively, the transporting and braking roles of the arrays of outlets can be reversed. As in the previous embodiment, fluid exiting the outlets 20A, 40 supports the article 12 without contact.

In a modification shown in Figures 12A and 12B, a movable wiper layer 48 can open and close the orifices 19 to turn on and off the fluid jets passing through the orifices. The wiper layer 48 also can reverse the direction of fluid flow through the orifices 19 to change the direction on the article 12. As the wiper layer 48 moves from the position in Figure 12A to that in Figure 12B, the fluid inlet is switched to change the fluid jet direction as shown.

This transport system for articles is relatively uncomplicated and has few moving parts, so partial or complete system failure is less likely. The transported article is highly stable and can be transported at relatively high controlled speeds and with the system 10 upside down or at any other

-12-

orientation, which can be advantageous.

In this arrangement, articles 12 having the proper area-to-weight ratio will be held to the working surface 16 of the planar element and can be transported in any orientation with excellent speed and directional control. Small outlets 20 expel fluid at high velocity differentials that hold the article 12 to the working surface 16 at a gap of about 0 to about 0.10 cm. An array of outlets 20 in the center of the working surface 16 tends to flatten a web or flexible article that is many times the width spacing of the outlets 20. Also, the fluid jets can control movement in the plane of the working surface 16 and can transfer articles 12 from one planar element to another as shown in Figure 13. Although the planar elements are shown as overlapping, they need not overlap.

In one embodiment, the diameter of the outlets 20, 40 is less than 0.152 cm and the article 12 is transported while being held to the planar element 14 at a distance of about 0 cm to about 0.10 cm to the working surface 16 and the velocity of the fluid ranges from about 100 to about 300 m/s. In another embodiment, an article was transported along a two dimensional circular path at speeds exceeding about 7.6 m/s using less than about 10 watts of power at a spacing with the working surface of less than about 0.015 cm. Depending upon the application, the orifices can be directed at any angle relative to the working surface.

In another example embodiment, the transport system is formed of a layered construction using three layers. (All dimensions are approximate.) The first layer 52 is 0.4 mm thick and is made of a vinyl material with adhesive on one side to adhere to the second layer. The second layer 56 is 0.4 mm thick and also is made of a vinyl material. The second layer

WO 94/02395

-13-

can have adhesive on both sides to adhere to the first and third layers. The third layer 60 is 0.1 mm thick and is made of stainless steel. The working surface 16 formed on the third layer 60 is 25 mm wide. This transport system has two arrays of orifices 19 and two arrays of outlets 20 are formed in the working surface 16. The outlets 20 are rectangular and have a width of 1.0 mm and length of 5.0 mm. The outlets are oriented at an angle with respect to a the centerline of the working surface of 30°. The outermost portion of the outlets 20 (from the centerline) is 3.5 mm from the side edge of the working surface, 14.0 mm from corresponding outlets on the other side of the centerline, and 12.0 mm from the same side of the adjacent outlet on the fluid. This path causes the outlet 20 to exit the fluid. This path causes linear, stepped path for the fluid. This path causes surface. This angle is defined, referring to Figure 2, as the angle formed between the diagonal line connecting the lower left and upper right corners of the outlet 20 formed in the third layer 60 and the thick and the outlet length is 5 mm.)

A transport system 27 cm long formed in a loop and having 45 outlets was used to transport a flexible tape which was 25.4 cm long, 2.54 cm wide, 25.4 microns thick, and was 0.22 grams. The air mass flow rate entering the inlet in the first layer ranged from 0.0006 kg/sec to 0.0010 kg/sec (the air velocity ranged from 27 m/sec to 235 m/sec with the directional component ranging from 23 m/sec to 204 m/sec). This produced an air velocity at the outlet of up to 300 m/sec transported the article at speeds of up to 1650 cm/sec.

-14-

Claims

1. A transport apparatus 10, 10A for transporting articles 12 comprising:

- 5           a working surface 16, 16A having a longitudinal centerline and two side edges, wherein the working surface 16, 16A is continuous and substantially smooth to permit fluid delivered to the working surface 16, 16A to exhaust off of the working
- 10          surface 16, 16A at the side edges of the working surface 16, 16A; and
- means for orientation independently transporting and supporting the article 12 along the working surface 16, 16A comprising a plurality of
- 15          orifices 19 terminating in outlets 20, 20A on the working surface 16, 16A for delivering the fluid to the working surface 16, 16A along first and second arrays which determines the transport path of the article 12, wherein the first and second arrays are
- 20          located on opposite sides of the longitudinal centerline of the working surface 16, 16A, wherein each of the outlets 20, 20A is oriented to deliver fluid at an angle with the direction of transport, the fluid flow 64 direction including a cross-directional
- 25          component 62 perpendicular to the direction of transport and a directional component 66 parallel to the direction of transport, and wherein the fluid flow 64 from the outlets 20, 20A of the first array does not impinge the fluid flow from the outlets 20, 20A of
- 30          the second array adjacent the working surface 16, 16A, wherein fluid exiting the outlets 20, 20A transports the article 12 along the working surface 16, 16A and supports the article 12 adjacent and spaced from the working surface 16, 16A while preventing the article
- 35          12 from contacting the working surface 16, 16A during transport.



-15-

2. The transport apparatus 10 of claim 1 wherein the working surface 16, 16A is at least as long as the articles 12 being transported.
3. The transport apparatus 10 of claim 1 wherein the outlets 20, 20A extend through the working surface 16, 16A to deliver fluid to the working outlet 20, 20A at an effective angle  $\alpha$  wherein each surface 16, 16A has a cross section on the working surface 16, 16A with a length-to-width ratio less than that governed by the equation  $l/w = 1/\sin \alpha$ .
4. The transport apparatus 10 of claim 1 wherein each outlet 20, 20A creates an angular, non-linear, stepped path for the fluid.
5. The transport apparatus 10 of claim 1 wherein the direction of the cross-directional component 62 of the fluid flow 64 direction of each outlet 20, 20A in the first array of outlets is away from that of each outlet 20, 20A in the second array of outlets 20, 20A and the directional component 66 of the fluid flow 64 direction of each outlet 20, 20A is in the direction of transport.
6. The transport apparatus 10 of claim 1 wherein the first and second arrays are linear and all of the outlets 20, 20A in each array are longitudinally colinear.
7. The transport apparatus 10 of claim 1 wherein when the article 12 is a thin, flexible web, and wherein the perpendicular distance from the first and second arrays of outlets 20, 20A to the respective working surface 16 side edges is selected to assist transporting the web without flexing, while maintaining the web in tension.

-16-

8. A method of transporting an article 12 having first and second opposing surfaces with the first surface 36 adjacent a continuous and substantially smooth working surface 16, 16A having side edges, wherein the working surface 16, 16A permits fluid delivered to the working surface 16, 16A to exhaust off of the working surface 16, 16A at its side edges, the method comprising the step of delivering a fluid to the first surface 36 of the article to orientation independently transport and support the article 12 along the working surface 16, 16A, wherein the delivering step comprises delivering fluid from two transverse locations on opposing sides of the longitudinal centerline of the working surface 16, 16A at each longitudinal location of the working surface 16, 16A, the fluid flow 64 direction including a cross-directional component 62 perpendicular to the direction of transport and a directional component 66 parallel to the direction of transport, wherein the direction of the cross-directional component 62 for each transverse location at a longitudinal location of the working surface 16, 16A is away from each other.

9. The method of claim 8 further comprising the step of causing the fluid to be delivered to the working surface 16, 16A at a perpendicular distance from the respective side edges of the working surface 16, 16A to assist exhausting of the fluid off of the working surface 16, 16A at the side edge of the working surface 16, 16A.

10. The method of claim 8 wherein the article 12 is flexible and further comprising the step of maintaining tension on the article 12 during transport to maintain the article 12 substantially planar and prevent flexing.

-17-

11. An apparatus 10 for transporting articles 12 comprising:

at least one article 12 to be transported;

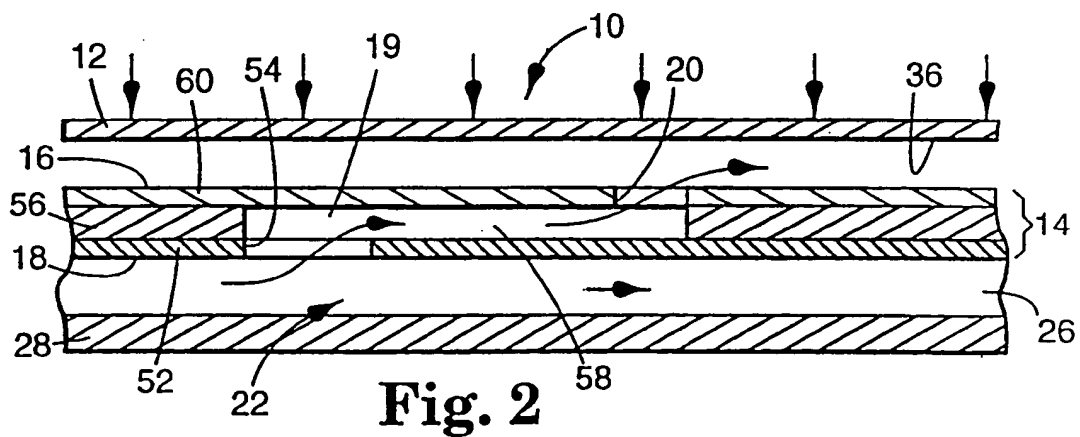
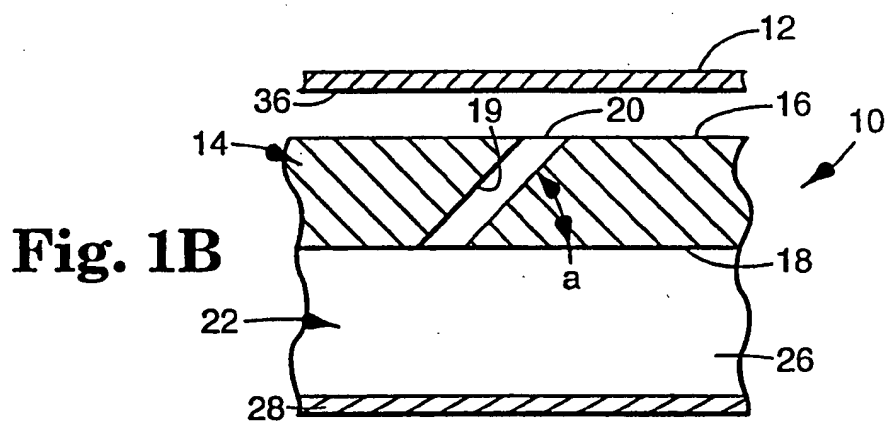
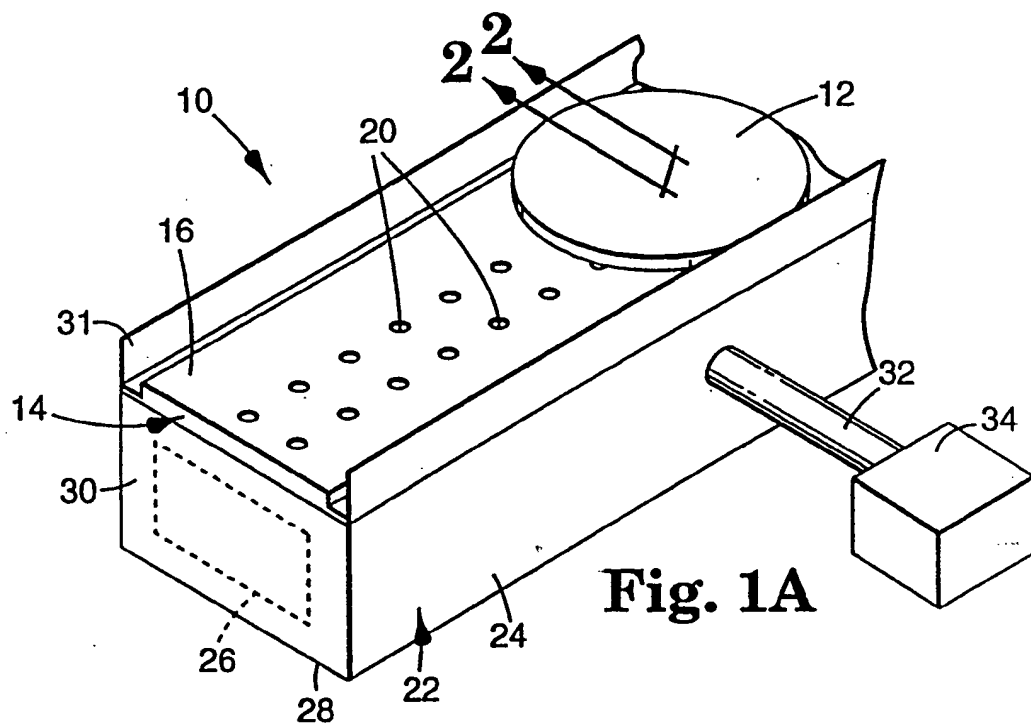
a working surface 16, 16A having a

5 longitudinal centerline and two side edges, wherein the working surface 16, 16A is continuous and substantially smooth to permit fluid delivered to the working surface 16, 16A to exhaust off of the working surface 16, 16A at the side edges of the working  
10 surface 16, 16A;

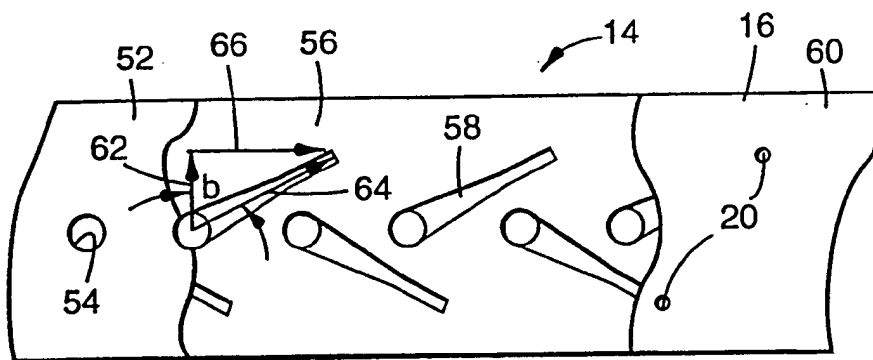
means for orientation independently transporting and supporting the article 12 along the working surface 16, 16A comprising a plurality of orifices 19 terminating in outlets 20, 20A on the  
15 working surface 16, 16A for delivering the fluid to the working surface 16, 16A along first and second arrays which determines the transport path of the article 12, wherein the first and second arrays are located on opposite sides of the longitudinal  
20 centerline of the working surface 16, 16A, wherein each of the outlets 20, 20A is oriented to deliver fluid at an angle with the direction of transport, the fluid flow 64 direction including a cross-directional component 62 perpendicular to the direction of  
25 transport and a directional component 66 parallel to the direction of transport, and wherein the fluid flow from the outlets 20, 20A of the first array does not impinge the fluid flow from the outlets 20, 20A of the second array adjacent the working surface 16, 16A,  
30 wherein fluid exiting the outlets 20, 20A transports the article 12 along the working surface 16, 16A and supports the article 12 adjacent and spaced from the working surface 16, 16A while preventing the article 12 from contacting the working surface 16, 16A during  
35 transport; and

means for delivering a supply of fluid to the orifices 19.

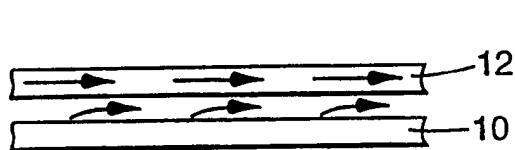
- 1 / 4 -



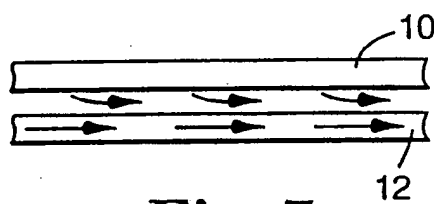
- 2 / 4 -



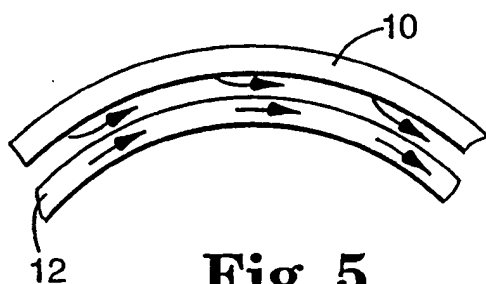
**Fig. 3**



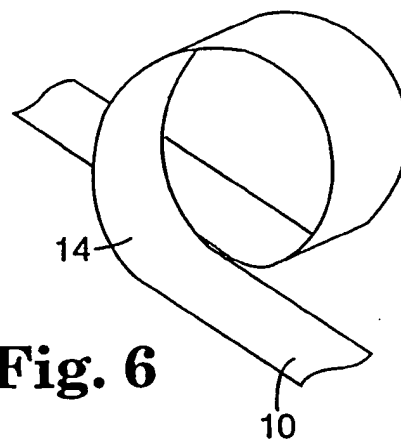
**Fig. 4**



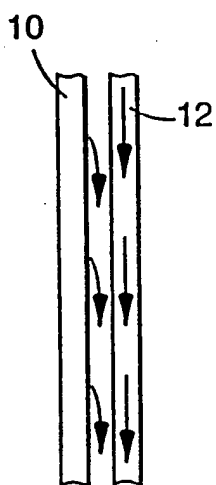
**Fig. 7**



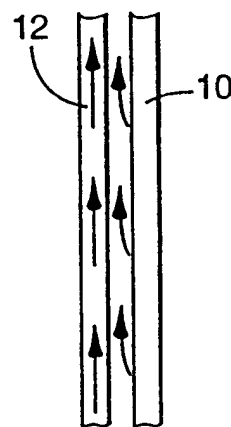
**Fig. 5**



**Fig. 6**

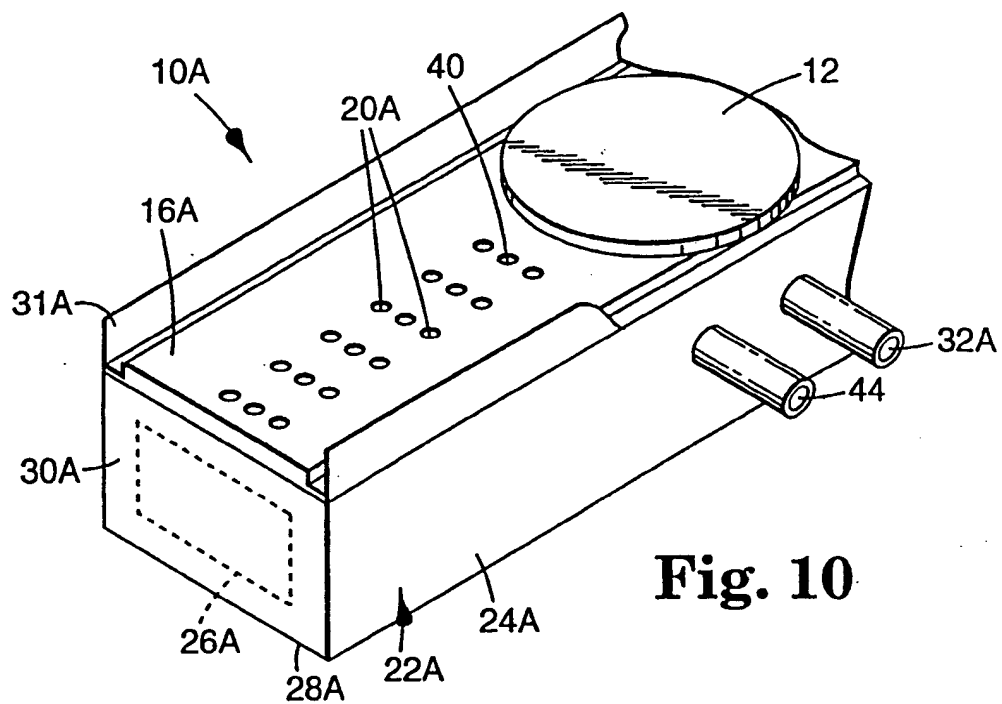


**Fig. 8**

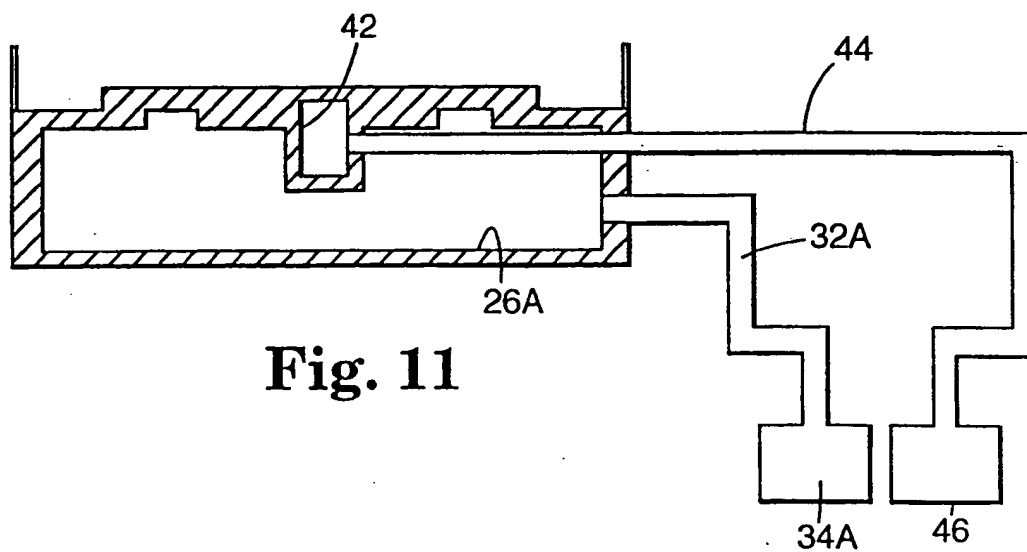


**Fig. 9**

- 3 / 4 -

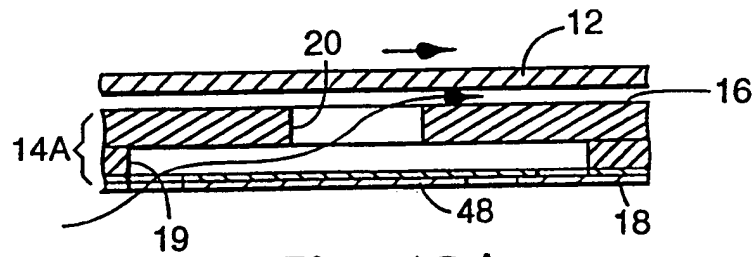


**Fig. 10**

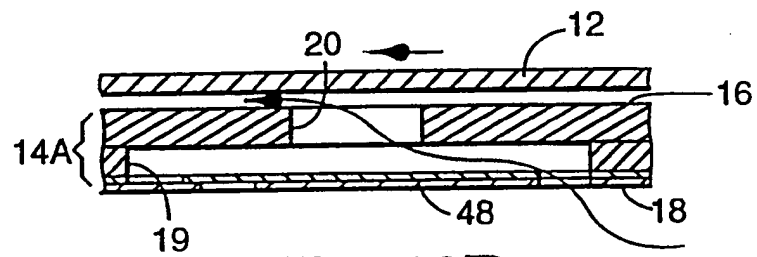


**Fig. 11**

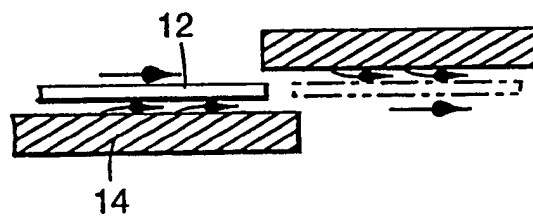
- 4 / 4 -



**Fig. 12A**



**Fig. 12B**



**Fig. 13**

## INTERNATIONAL SEARCH REPORT

PCT/US 93/06147

International Application No

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.Cl. 5 B65G51/03; H01L21/00		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
Int.Cl. 5	B65G ; H01L ; G11B	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
X	FR,A,2 131 976 (INTERNATIONAL BUSINESS MACHINES CORPORATION) 17 November 1972 see page 2, line 24 - line 27 see page 3, line 7 - line 28 see page 4, line 5 - line 19; figures ----	1,2,5,8, 11
A	DE,B,1 251 220 (THE SINGER COMPANY) 28 September 1967 see the whole document ----	1,2,8
A	GB,A,2 012 699 (VITS-MASCHINENBAU GMBH) 1 August 1979 see page 3, line 16 - line 40; figures -----	1,5,7,8, 10,11
<p><sup>10</sup> Special categories of cited documents :</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"A" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search		Date of Mailing of this International Search Report
07 OCTOBER 1993		19. 10. 93
International Searching Authority EUROPEAN PATENT OFFICE		Signature of Authorized Officer VAN ROLLEGHEM F.



**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.**

US 9306147  
SA 76884

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.  
The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

07/10/93

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR-A-2131976	17-11-72	DE-A,C 2213842	12-10-72
		GB-A- 1326334	08-08-73
		US-A- 3706475	19-12-72
-----			
DE-B-1251220		None	
-----			
GB-A-2012699	01-08-79	DE-A- 2802610	26-07-79
		CH-A- 637089	15-07-83
		JP-A- 54104167	16-08-79
		US-A- 4218001	19-08-80
-----			

